BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 05040

SUBJECT: Combined Skylab and Lunar Support With A Reduced Manned Space Flight Network - Case 900

DATE: May 22, 1970

FROM: J. E. Johnson

ABSTRACT

Present schedules call for Manned Space Flight Network support of up to five separate lunar data sources simultaneously during the active period of Skylab 1/2. These sources are Apollo Lunar Surface Experiment Packages to be left on the moon by Apollo's 14, 15, 16 and 17, and a satellite left in lunar orbit by Apollo 16. Consideration is being given to reducing the Manned Space Flight Network from its present complement of 12 stations. A companion study has shown that a 9 or 10 station network can adequately support Skylab. This memorandum shows that such a 9 station or a 10 station network can also simultaneously provide adequate lunar support. At least two stations, one of them a deep-space station, can be made available continuously to provide lunar support without significantly impairing Skylab support.

In this study, a 9 station network and a 10 station network were scheduled for simultaneous lunar and Skylab support over a four day period in July, 1972. With two stations always supporting lunar projects, about 17% of all possible Skylab contacts would be foregone with a 10 station network. With a 9 station network, about 24% of all possible contacts would be foregone. In no case over the four day period would a requirement for two station, around-the-clock lunar support introduce a gap between Skylab contacts exceeding the recording capacity of the Skylab Apollo Telescope Mount tape recorder. Three such gaps exist over the four days for both a 9 and 10 station network independently of the need for lunar support.

The results of this study, while confined to a specific four day interval, should be generally valid for any time simultaneous support is required.

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MEMORANDUM FOR FILE

The Manned Space Flight Network (MSFN) consists of 12 stations - 9 stations with 30 foot diameter antennas,[1] and 3 deep-space stations with 85 foot diameter antennas (see Table 1 and Figure 1). A memorandum by J. P. Maloy (Ref. 1)[2] examines the coverage available for Skylab if different stations or combinations of stations were to be deleted. This memorandum extends the results of that study to consider the need for support by the MSFN of Apollo Lunar Surface Experiment Packages (ALSEP's) and a subsatellite orbiting the moon in the Skylab time frame. The focus of these two memorandums is to suggest ways of reducing requirements on MSFN operating facilities without significantly impairing operational support.

Considering only Skylab, Reference 1 suggests that a reasonable MSFN configuration would consist of 9 stations, with Corpus Christi, Texas, Canary Island and Guam deleted (Figure 2). Texas is shown to contribute almost nothing to Skylab support, Canary Island somewhat more, and Guam more yet, but not enough to be essential. Still further MSFN deletions, or other combinations, were judged to be detrimental to adequate support. For example, the deletion of either Guam or Ascension Island by itself was not significant, but deletion of both was judged significant and inadvisable. This is the result of Ascension and Guam being nearly diametrically opposed (antipodal). A Skylab revolution that will miss an Ascension contact will usually also miss Guam, and many extra long coverage gaps will result.

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[1]Actually, 8 at this time. A Santiago, Chile station is firmly planned for the near future. The network also includes a ship (Vanguard), which is used primarily for launch coverage and is not considered in this memorandum.

[2]Ref. 1 - "Effect of Manned Space Flight Network Reduction on Skylab Support," Case 900, by J. P. Maloy, May 22, 1970.

This memorandum examines in detail a four day period when, following present schedules, Skylab 1/2 will be in orbit, four ALSEPs will be active on the lunar surface, and a subsatellite will be orbiting the moon. All would require MSFN support. The time period chosen was from July 25 to July 28, 1972. This represents something very close to a worst - case work load on the MSFN. Two MSFN support schedules were set up, one for a 10 station network (deleting Texas and Canary), and the second for a 9 station network (also deleting Guam). One 85'- station and one 30'- station were assumed to be looking at the moon at all times. Under these conditions, it is shown that a very high degree of Skylab support could be maintained. Furthermore, due to the high day-to-day correlation of Skylab contacts and lunar visibility, the conclusions should be generally true over an extended period of time. A 9 or 10 station MSFN could provide almost as much meaningful support for Skylab and lunar projects as the present 12 station MSFN.

Support Requirements

Skylab. Skylab support requirements are basically the same as for earlier manned, extended duration, earth-orbital missions. As a design objective, there should be at least one contact per revolution of sufficient length to permit tracking, voice communications, command, and real-time and tape dump telemetry. Additional contacts per revolution may be required to support powered flight maneuvers and some of the experiments. Scheduling of these events can usually be planned for periods of good MSFN coverage.

An additional constraint will be placed on the MSFN by the capacity of the Apollo Telescope Mount (ATM) tape recorder. Its record capacity is about 90 minutes (as measured, it is closer to 89 minutes) at a 4 kbps rate. The tape is a continuous loop, and is played back at a 72 kbps rate. There is no reverse capability. Consequently, a tape dump will require about five minutes, independent of the length of recorded data. Allowing time for acquisition of signal and commanding, a six minute contact will be about the minimum allowable for an ATM tape dump. Such contacts will be required at least once every 89 minutes while the ATM experiments are active (which will be most of the time), or data will be lost. A spare recorder of the same type will be on board, but its usage is intended to be limited to keep it in readiness as a back-up.

ALSEP. ALSEP support requirements include:

- Continuous real-time (data to the Mission Control Center) support for the first 45 days after ALSEP emplacement.
- Two hours of continuous real-time support every 24 hours thereafter, except:
  - Sixty hours continuous real-time support from 12 hours before a terminator crossing to 48 hours after.
- Command capability.
- Continuous record-only support at all other times throughout the ALSEP lifetime (nominally two years).
- Any 30' or 85' station to be capable of record-only support of up to 3 ALSEP's simultaneously.

ALSEP's from Apollo missions 14, 15, 16 and 17 will be active during Skylab 1/2 activity periods if the present schedules are maintained and the ALSEP's function properly.

Subsatellite. Lunar subsatellite requirements are not presently well defined. Present thinking is:

- Telemetry support for about 16 minutes per lunar revolution (about two hours). This may require use of an 85' antenna.
- Command capability when the satellite is visible.
- Doppler tracking for at least one revolution per day, using an 85' station and possibly also a 30' station.

Lunar subsatellites are planned for Apollo missions 16 and 18. They will have one year lifetimes and Apollo 16's will be active in the Skylab 1/2 time frame if schedules are maintained.

Lunar support could therefore require reception of 4 ALSEP downlinks simultaneously, plus a subsatellite downlink briefly once every two hours, and at least a one and one-quarter hour period of two-way doppler tracking per day.

Network Scheduling for Simultaneous Support. Lunar and Skylab visibility data were calculated for a four day period early in the mission of Skylab 1/2, arbitrarily assuming a July 15, 1972 launch date for Skylab 1 (the workshop). The period chosen for network scheduling was from July 25 through July 28, 1972, midnight-to-midnight EST. The Skylab orbital assembly was assumed to be in a 235 nm circular orbit with a 50° inclination. MSFN visibility of the moon and Skylab is shown and described in Appendix A.

Appendix B demonstrates a trial schedule for a 10 station network (deleting Texas and Canary) using the visibility data from Appendix A. Appendix C does the same for a 9 station network (also deleting Guam).

The scheduling shown in Appendixes B and C is for illustration only, and is not necessarily optimum. It makes maximum feasible use of the network, and does not consider possible manpower constraints, or support of other space projects. The intent of this exercise was to determine if a 9 or 10 station network could provide adequate support for what is close to worst-case manned spaceflight loading. A 9 station network appears satisfactory, assuming it can operate reliably with a high degree of utilization over an extended period of time.

Skylab coverage will be highly correlated from day to day, as is evident from Figs. A-1 to A-4. Lunar visibility varies gradually from day to day over the lunar month. For the four days shown, the moon will have a southern declination. Since the 9 station network has five northern latitude sites and four southern latitude sites, choice of a different time during the lunar month should not affect the conclusions significantly.

General guidelines used for this trial scheduling include the following:

- One station could not simultaneously support both Skylab and lunar activity (not necessarily a realistic assumption, see below).

- A primary objective was to minimize long periods without Skylab contacts, not necessarily limited to periods in excess of 89 minutes.

- A station was not scheduled for lunar support unless the station could maintain lunar visibility for a reasonable period, at least four to five hours.

- A station was not scheduled to support a Skylab contact not repeated on the next revolution unless that contact appeared particularly useful.

- Turnaround time to reconfigure between lunar and Skylab support was taken to be two hours. Get-ready and turn-down times, without reconfiguration, were taken to be one hour each. Turnaround and get-ready times could overlap if a station were to go directly from one configuration to another.

Results

Statistics for this trial scheduling are given in the Appendixes. Tables B-1 and C-1 itemize station support times including reconfigure, get-ready and turn-down times. These times vary from 7 to 23 hours per day, and average slightly over 15. Note that stations such as Santiago and Honeysuckle Creek at this time of the lunar month have lunar visibility generally coincident with Skylab contacts, and are assumed incapable of supporting both. At different times in the month, different station would encounter this situation.

Tables B-2 and C-2 show the potentially available Skylab contacts that would be lost due to lunar support. About 17% would be lost with a 10 station network, about 24% with a 9 station network.

Tables B-3 and C-3 show the number of gaps between Skylab contacts of six or more minutes duration. This scheduling did not introduce any new gaps exceeding the 89 minute capacity of the ATM recorder. The three gaps exceeding this capacity will exist independently of the removal of stations for lunar support.

Figures B-5 and C-5 illustrate the density of Skylab contacts of three minutes or longer. There will be at least one contact on every revolution during this period with both a 10 and 9 station MSFN. It can be seen from these figures that most of the Skylab contacts lost will come from revolutions that already have a large number of contacts. The 17% and 24% lost contacts shown in Tables B-2 and C-2 are hence believed to be misleading, and actual operational support would not be impaired by that great a percentage.

It may be feasible to provide simultaneous dual mission support by a single station. For example, VHF real-time support of Skylab would not necessarily be incompatible with simultaneous S-band record-only support of lunar projects.

It may also be feasible to consider lunar support by only one station around the clock, instead of the two assumed here. One station can receive as many as four downlinks simultaneously, and the worst-case downlink situation would be five. Even if this situation were to exist, it might be reasonable to forego data from the oldest (or least interesting) of the active lunar data sources. Additional equipment at a station could also be considered. An examination of the relative feasibility or desirability of these options is beyond the scope of this study.

Conclusions

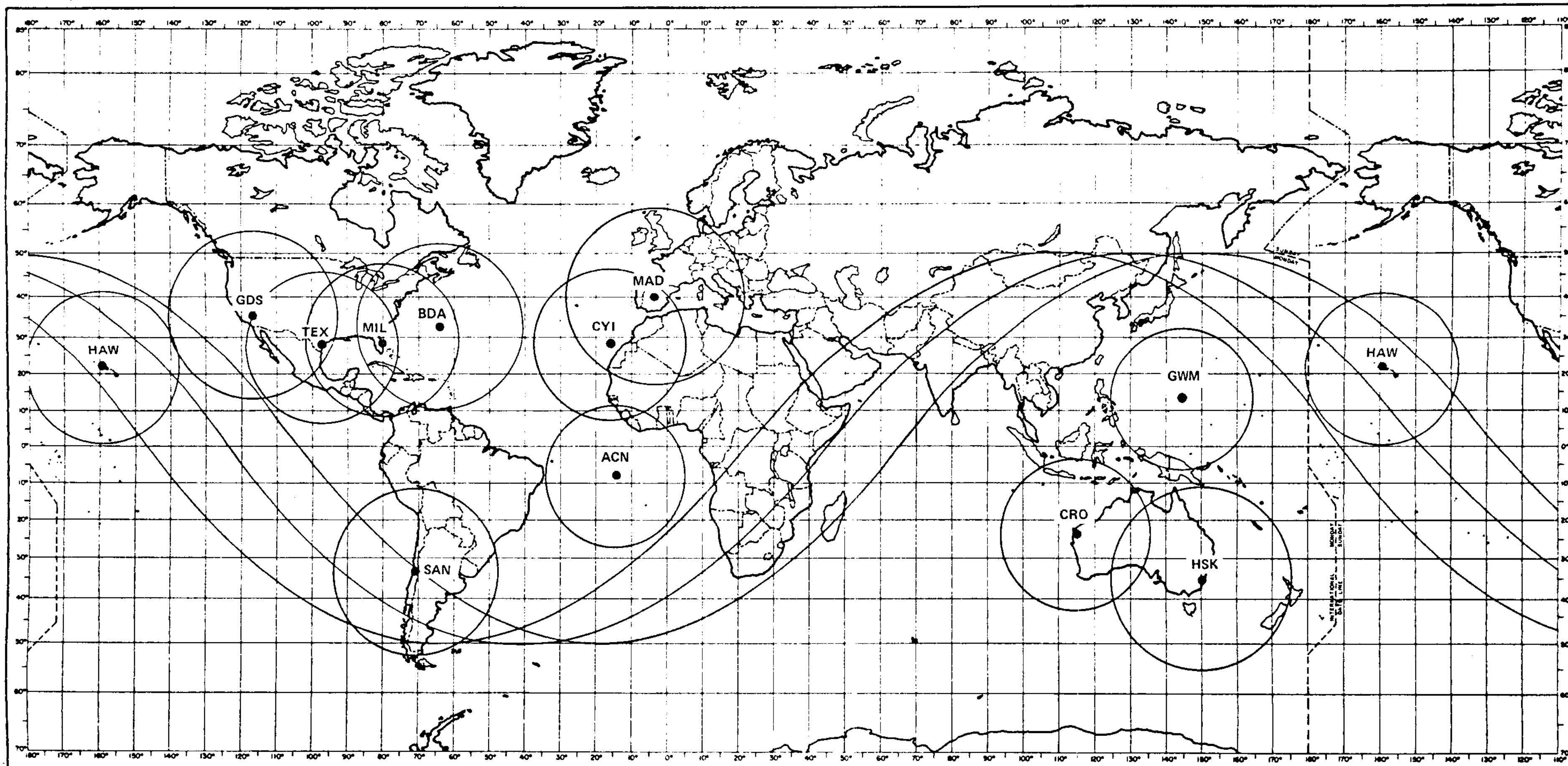
Ref. 1 shows that a 9 station MSFN can provide almost as much Skylab support as the presently planned 12 station MSFN. Any reduction below 9 stations will significantly impair Skylab support, independent of the need to support any other projects. This study shows that a 9 station MSFN can also readily provide around-the-clock lunar coverage, with at least one 85' station and one 30' station dedicated to ALSEP and lunar subsatellite support at all times.

The 9 station network suggested is: Merritt Island, Fla. (MIL), Bermuda (BDA), Madrid (MAD), Ascension Island (ACN), Carnarvon, Aust. (CRO), Honeysuckle, Aust. (HSK), Hawaii (HAW), Goldstone, Calif. (GDS), and Santiago, Chile (SAN). Station candidates for deactivation are, primarily Corpus Christi, Tex. (TEX), next Canary Island (CYI), last Guam (GWM). Ascension Island (ACN) could be substituted for GWM, with a slight penalty.

J. E. Johnson

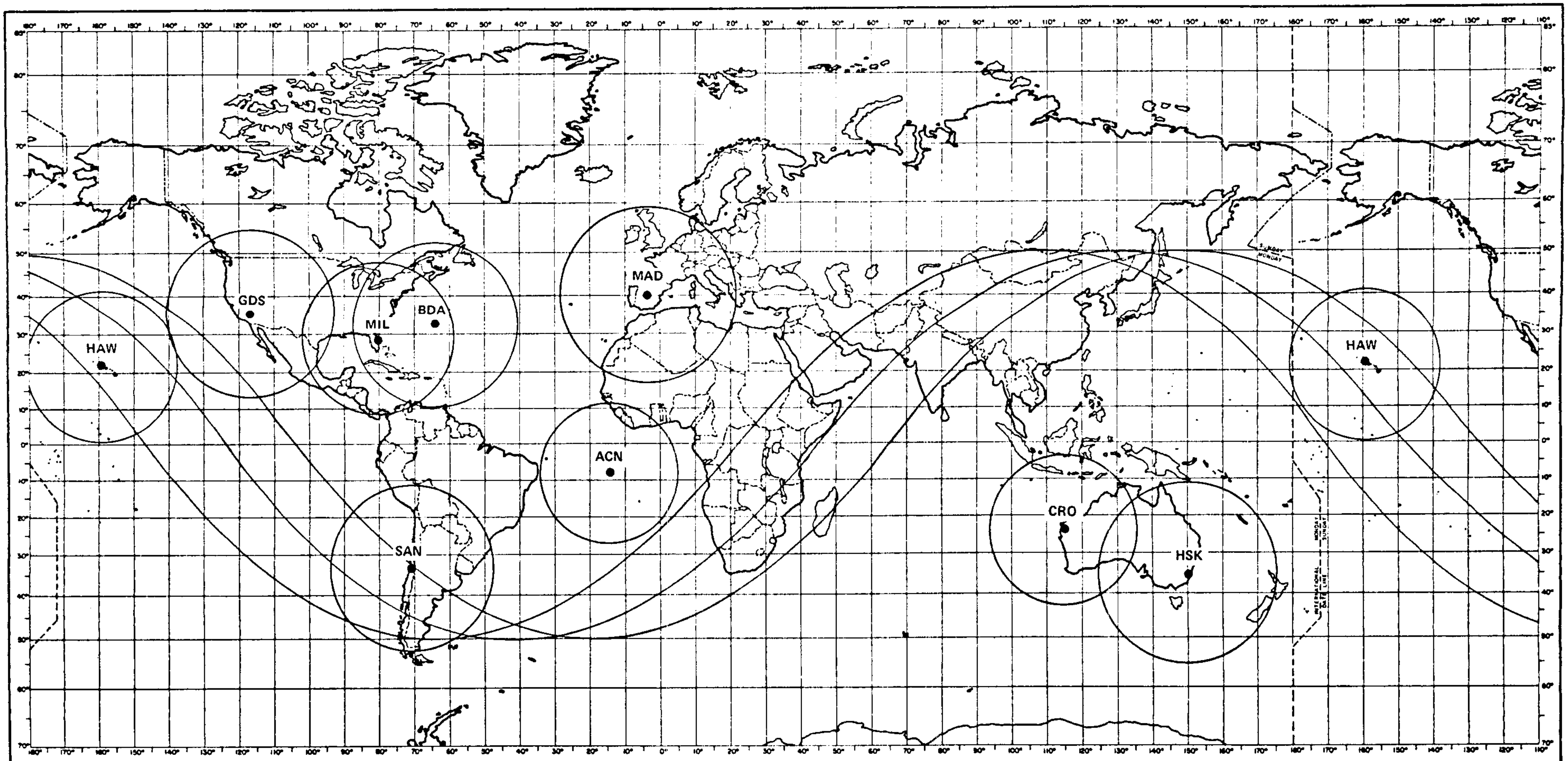
2034-JEJ-ms J. E. Johnson

Attachment
Figures 1 and 2
Table 1



STATION COVERAGE CIRCLES SHOW
VISIBILITY ABOVE 2° ELEVATION
FOR 235 NM ALTITUDE VEHICLE

FIGURE 1 - TWELVE STATION MSFN



STATION COVERAGE CIRCLES SHOW
VISIBILITY ABOVE 2° ELEVATION
FOR 235 NM ALTITUDE VEHICLE

FIGURE 2 - NINE STATION MSFN

TABLE 1

MANNED SPACE FLIGHT NETWORK STATIONS

	Code	Antenna Size	Latitude	Longitude
Merritt Island, Fla.	MIL	30'	28°30'N	80°42'W
Bermuda	BDA	30'	32°21'N	64°39'W
Canary Island	CYI	30'	27°46'N	15°38'W
Madrid, Spain	MAD	85'	40°27'N	4°11'W
Ascension Island	ACN	30'	7°57'S	14°20'W
Carnarvon, Australia	CRO	30'	24°54'S	113°43'E
Honeysuckle Creek, Australia	HSK	85'	35°35'S	148°59'E
Guam	GWM	30'	13°19'N	144°44'E
Hawaii	HAW	30'	22°07'N	159°40'W
Goldstone, California	GDS	85'	35°21'N	116°52'W
Corpus Christi, Texas	TEX	30'	27°39'N	97°22'W
Santiago, Chile (planned)*	SAN	30'	33°09'S	70°40'W

*Santiago is particularly useful as a gap-filler station for extended Earth-orbital missions such as Skylab. This station does not presently exist; however, it is firmly planned and can be considered as a part of the MSFN during this period. The Grand Bahama Island station will most likely be relocated to equip the Santiago station.

APPENDIX A

LUNAR AND SKYLAB VISIBILITY BY THE MSFN

Figures A-1 to A-4 show lunar and Skylab visibility by the MSFN for the period from July 25 to July 28, 1972. Each figure covers one day, midnight to midnight, EST. A Skylab workshop launch date of 3 p.m. EST, July 15, was arbitrarily assumed. This places the start of the visibility data at nine days and nine hours of ground elapsed time (GET) for the Skylab 1/2 mission. The orbital assembly is assumed to be in a 235 nm circular orbit with a 50° inclination.

The figures show Skylab visibility for each station by means of dots. Due to the condensed time scale on the figures, no attempt was made to show the duration of the visibility. However, only those passes having at least 3 minutes of visibility above 2° elevation relative to a smooth Earth were plotted. Furthermore, those passess having less than six minutes of visibility (the minimum considered necessary for an ATM tape dump) were identified by an asterisk immediately to the right of the dot. The number of contacts an any specific evaluation may be determined by scanning down the page at a slight diagonal to account for the 100-minute period of the Skylab orbit (relative to a rotating Earth).

Lunar visibility is indicated by straight lines. For this period, the moon will have a southern declination;

APPENDIX A

therefore, southern latitude stations will see it longer than northern latitude ones. For lunar visibility, a 5° elevation angle above a smooth Earth was used. This reflects the higher elevation angles generally required for S-band communications compared with the predominately VHF communications to be used by Skylab.

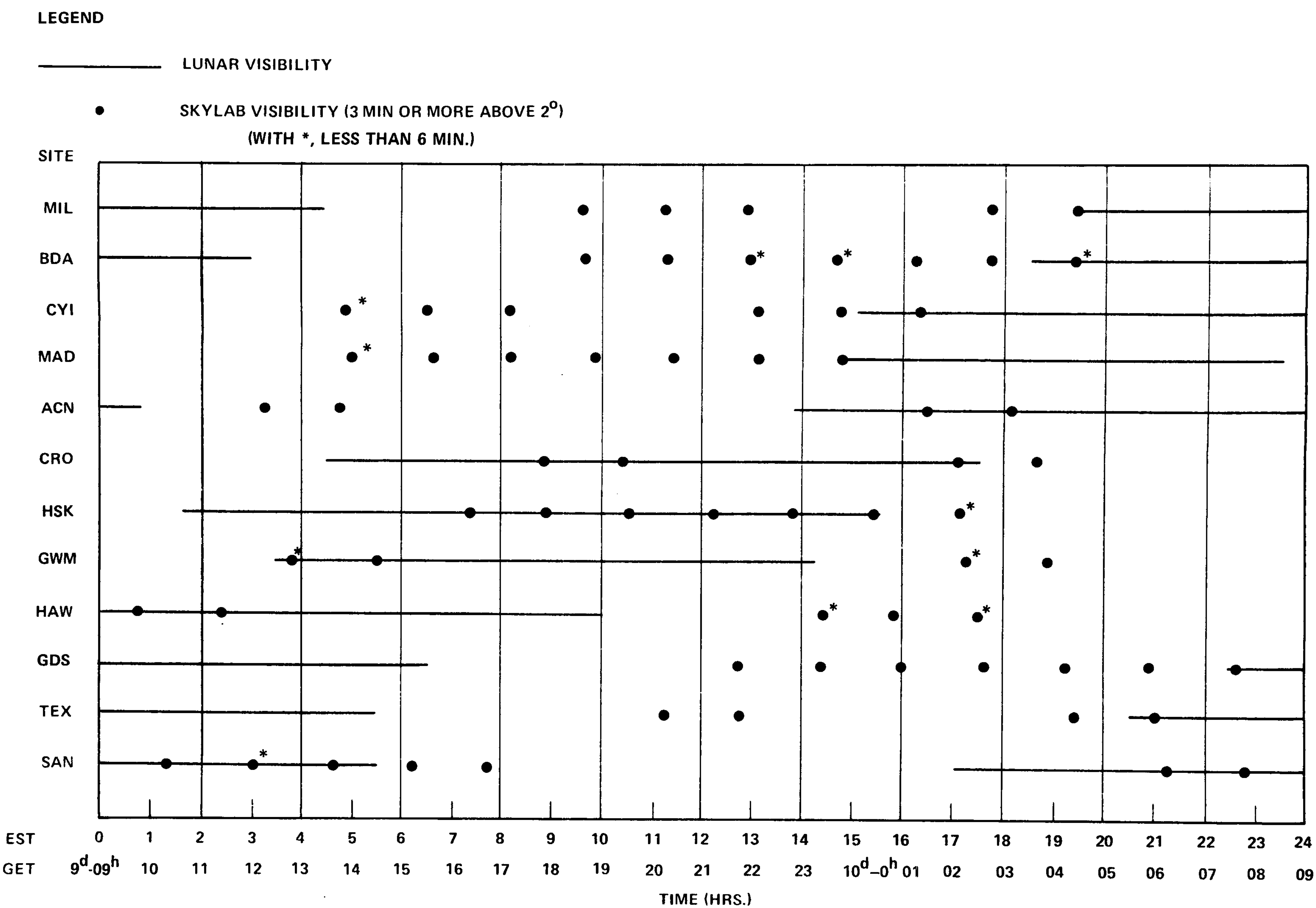


FIGURE A-1 - LUNAR AND SKYLAB VISIBILITY BY MSFN - JULY 25, 1972

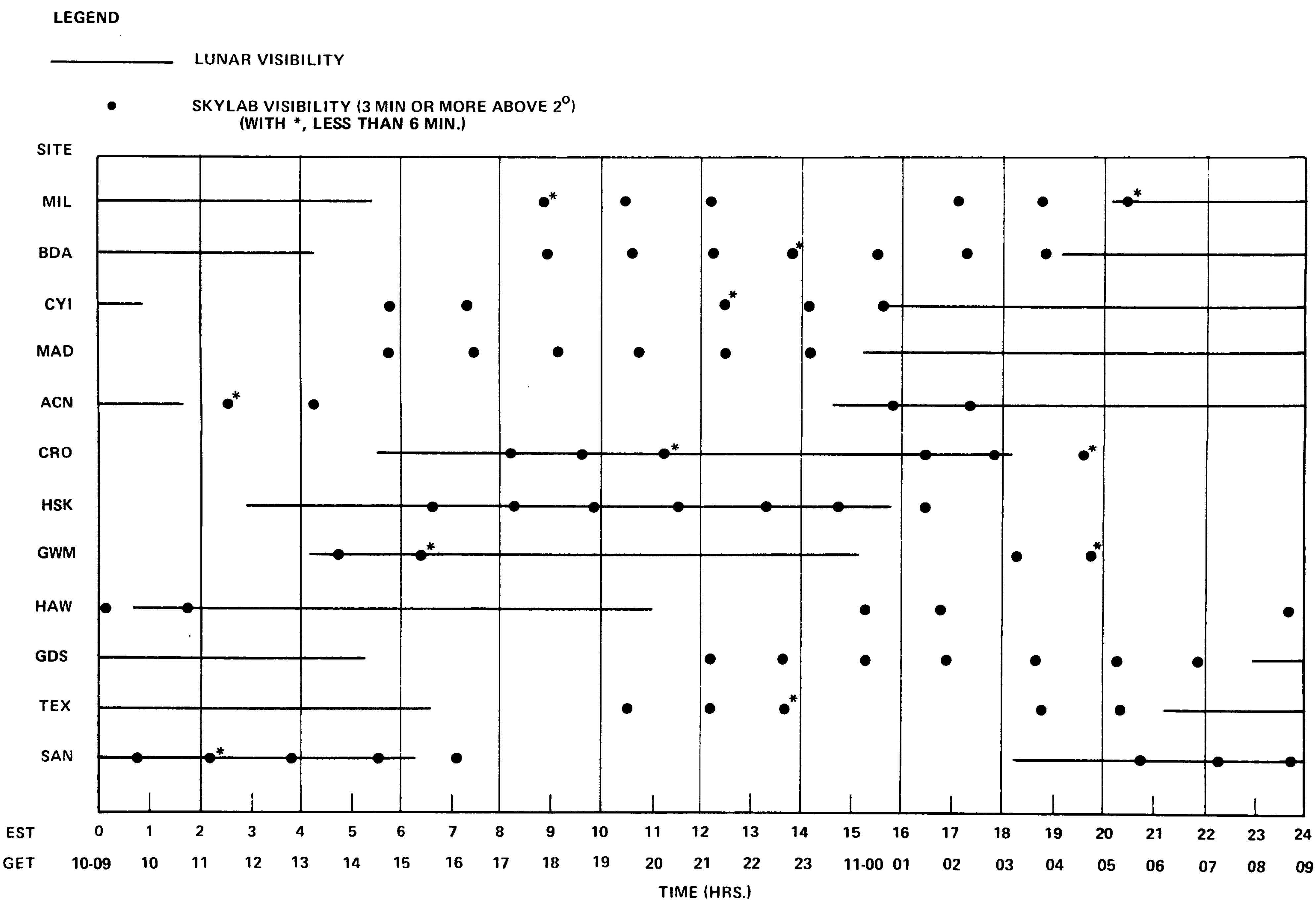


FIGURE A-2 - LUNAR AND SKYLAB VISIBILITY BY MSFN - JULY 26, 1972

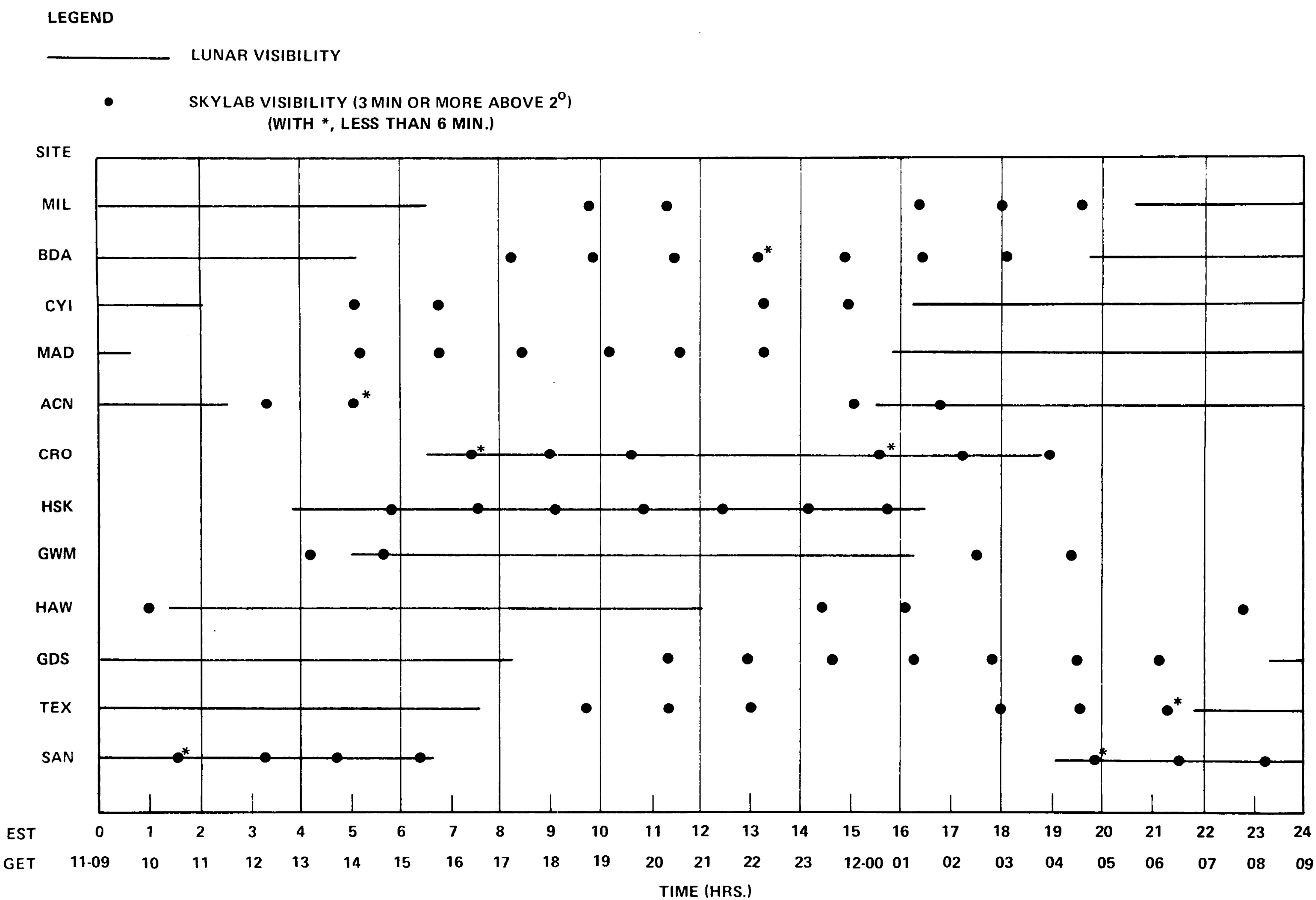


FIGURE A-3 - LUNAR AND SKYLAB VISIBILITY BY MSFN - JULY 27, 1972

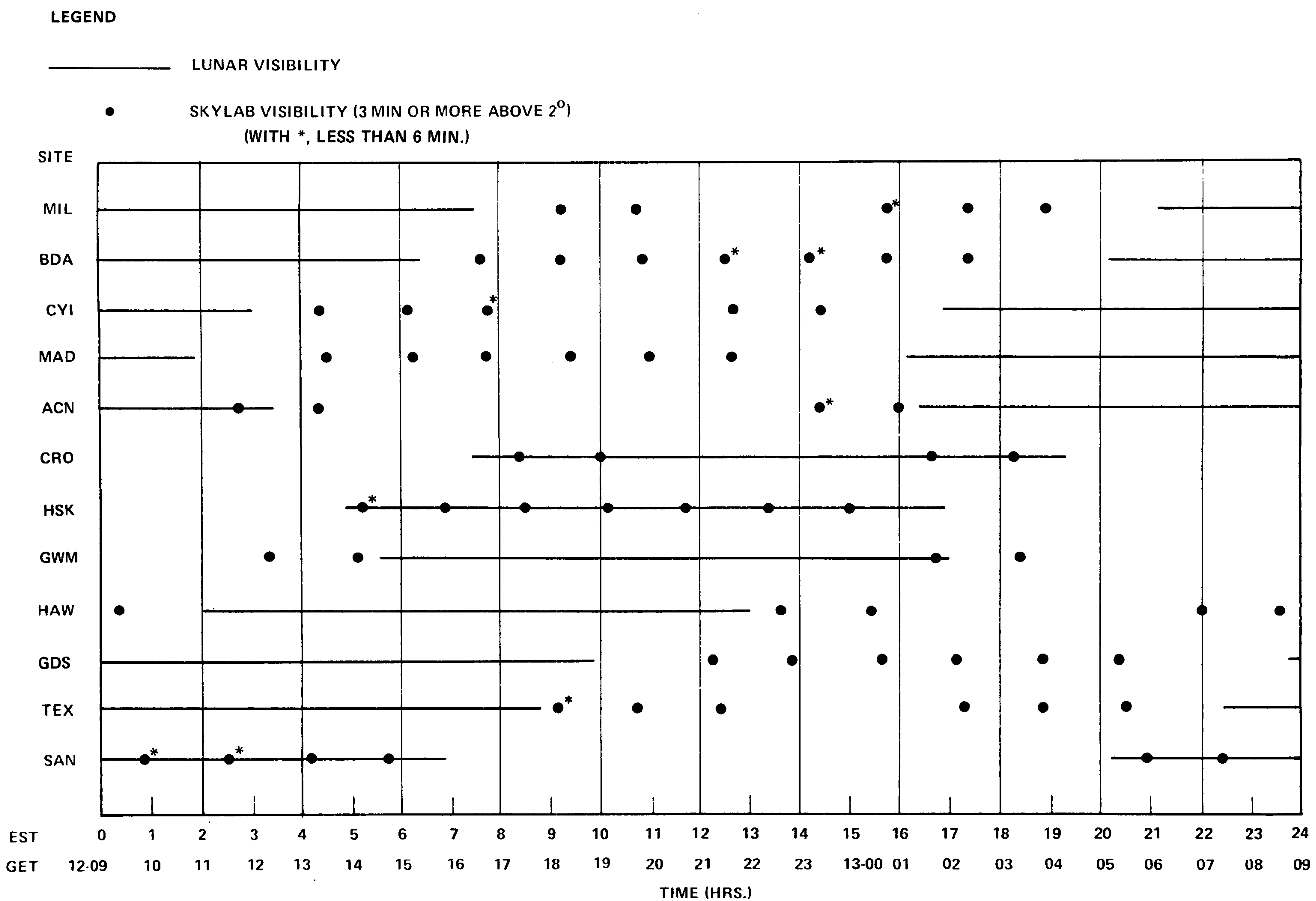


FIGURE A-4 - LUNAR AND SKYLAB VISIBILITY BY MSFN - JULY 28, 1972

APPENDIX B

TRIAL SCHEDULING FOR A TEN-STATION MSFN

Figures B-1 to B-4 overlay a possible support schedule on the data from Figures A-1 to A-4. The Texas and Canary stations have been deleted. Skylab support is denoted by circling the dot representing visibility. Lunar support is denoted by a shaded bar over the thin line showing lunar visibility. An 85' station (MAD, HSK, or GDS) was continuously assigned to lunar support, and one of the 7 remaining 30' stations was also continuously assigned to lunar support. The extensions of the bars before and after both Skylab and lunar support periods represent times for reconfiguring from one type of support to the other (two hours), pre-pass activity (one hour), and past-pass activity (one hour).

Skylab contacts potentially available for a specific revolution are tabulated at the bottom along with the potential contacts not supported due to lunar support.

Figure B-5 summarizes for the four-day period the density of Skylab contacts per revolution, with respect to what is potentially available and what has been scheduled. There will be at least one contact of three minutes or more on every revolution. The trial scheduling has increased by one (from two to three) the number of revolutions having only one

APPENDIX B

Skylab contact per revolution. Similarly it has increased by 3 (from 12 to 15) the number of revolutions having only 2 contacts per revolution. It has decreased by 10 (from 12 to 2) the number of revolutions having 6 or more contacts per revolution. The foregone Skylab contacts have thus been selected almost entirely from those revolutions having a high density of Skylab visibility. The reduction of Skylab support from, say, six to five contacts per revolution is not likely to be of any operational importance.

Table B-1 totals the scheduled support times for both Skylab and lunar support for each station, including the reconfigure, get-ready, and turn-down times. No attempt was made to equalize times between stations. Since maximum feasible support for Skylab was a scheduling guideline, the totals for most stations are quite high and in general would require two-shift manning. It might be decided that adequate Skylab support could be provided with a sharp reduction in total support time; however, some stations would still most likely require second shifts.

Table B-2 totals the potential Skylab contacts that would be lost due to lunar support. About 17% of the potential contacts would be lost with this support schedule.

Table B-3 shows the Skylab coverage gaps exceeding one hour between six-minute contacts. There are 29 such gaps, all but 3 of them being short enough to avoid loss of ATM tape

tape recorded data. These three gaps would exist independently of lunar support requirements.

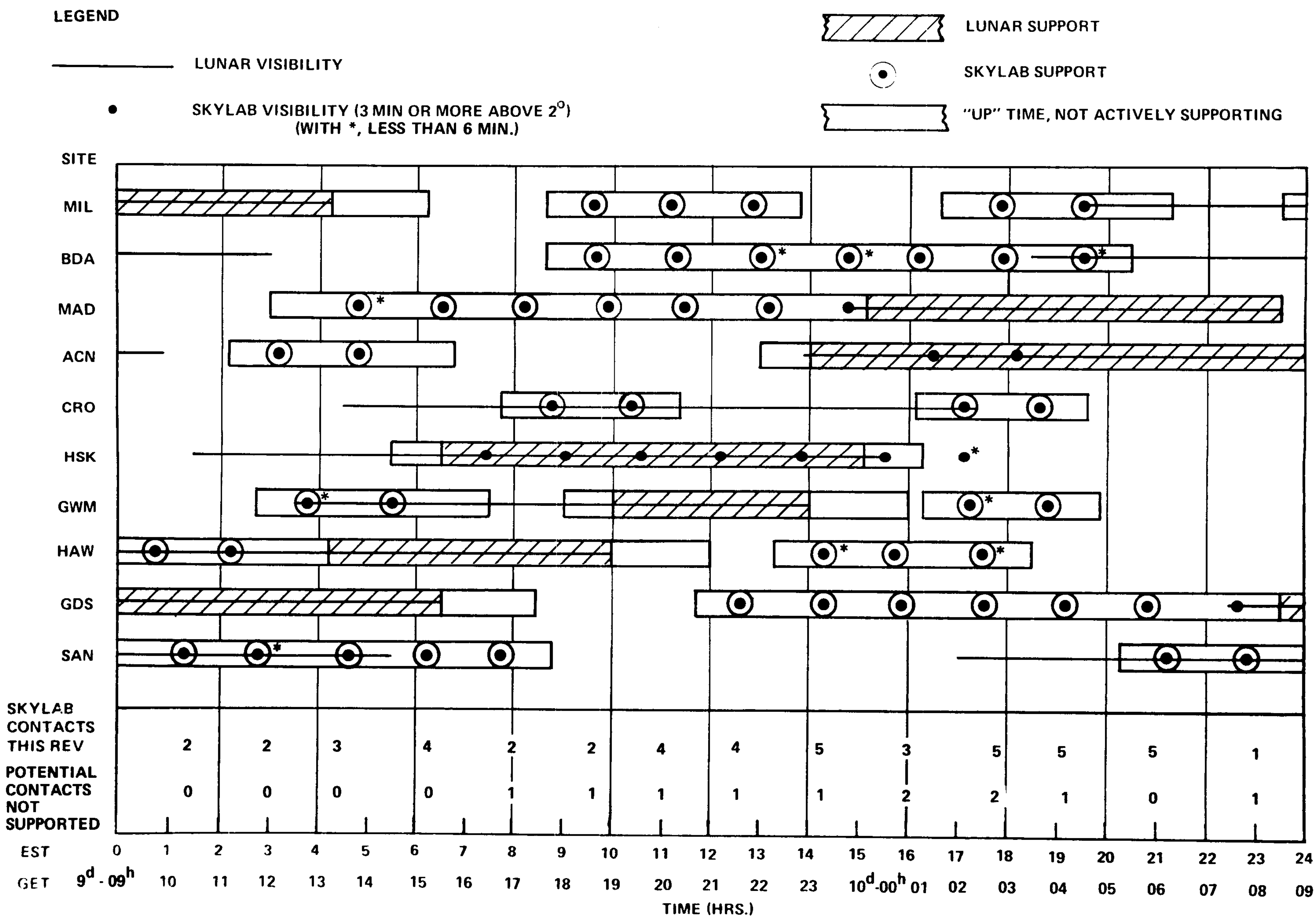


FIGURE B-1 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 25, 1972
(10 STATION NETWORK)

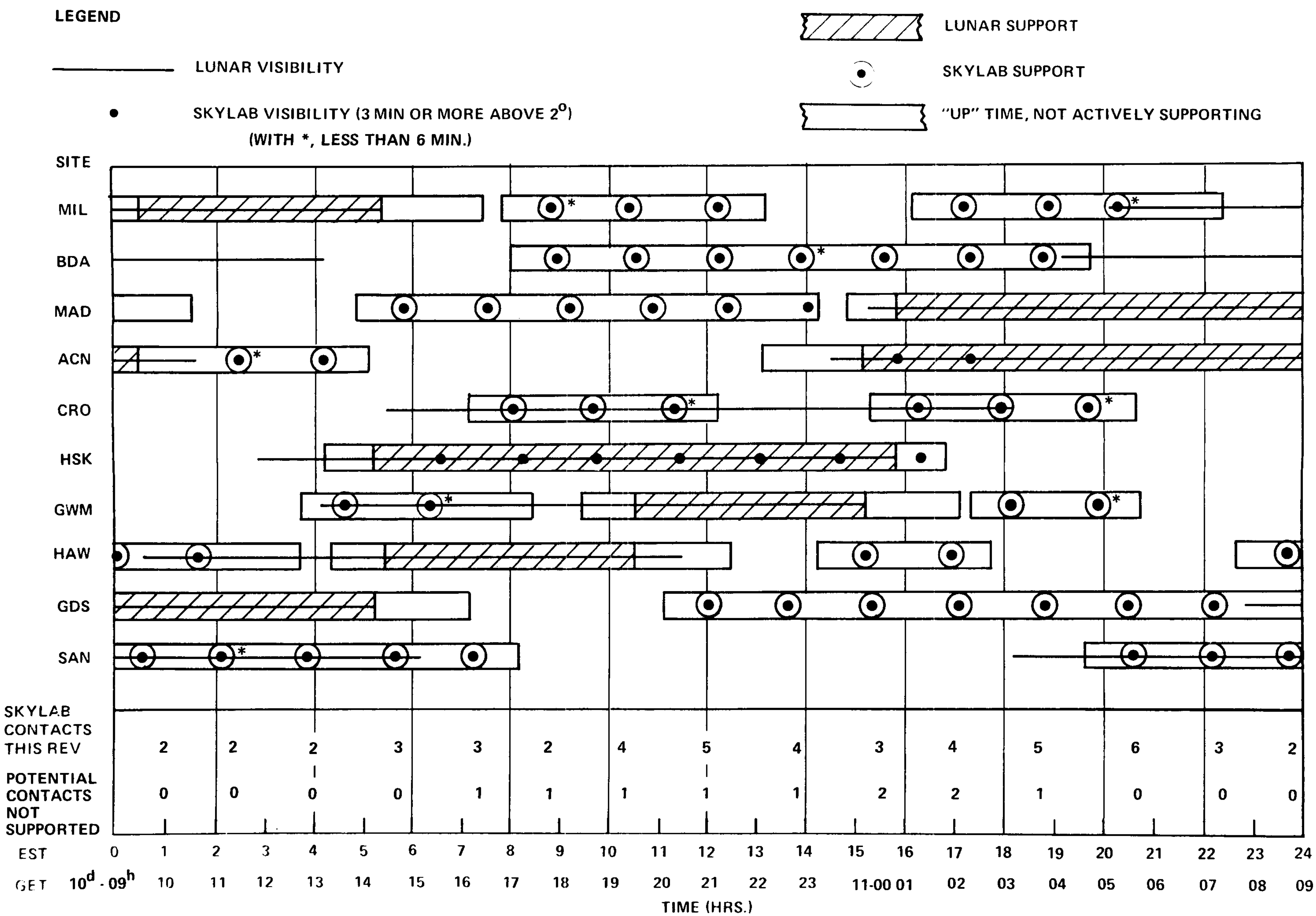


FIGURE B-2 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 26, 1972
(10 STATION NETWORK)

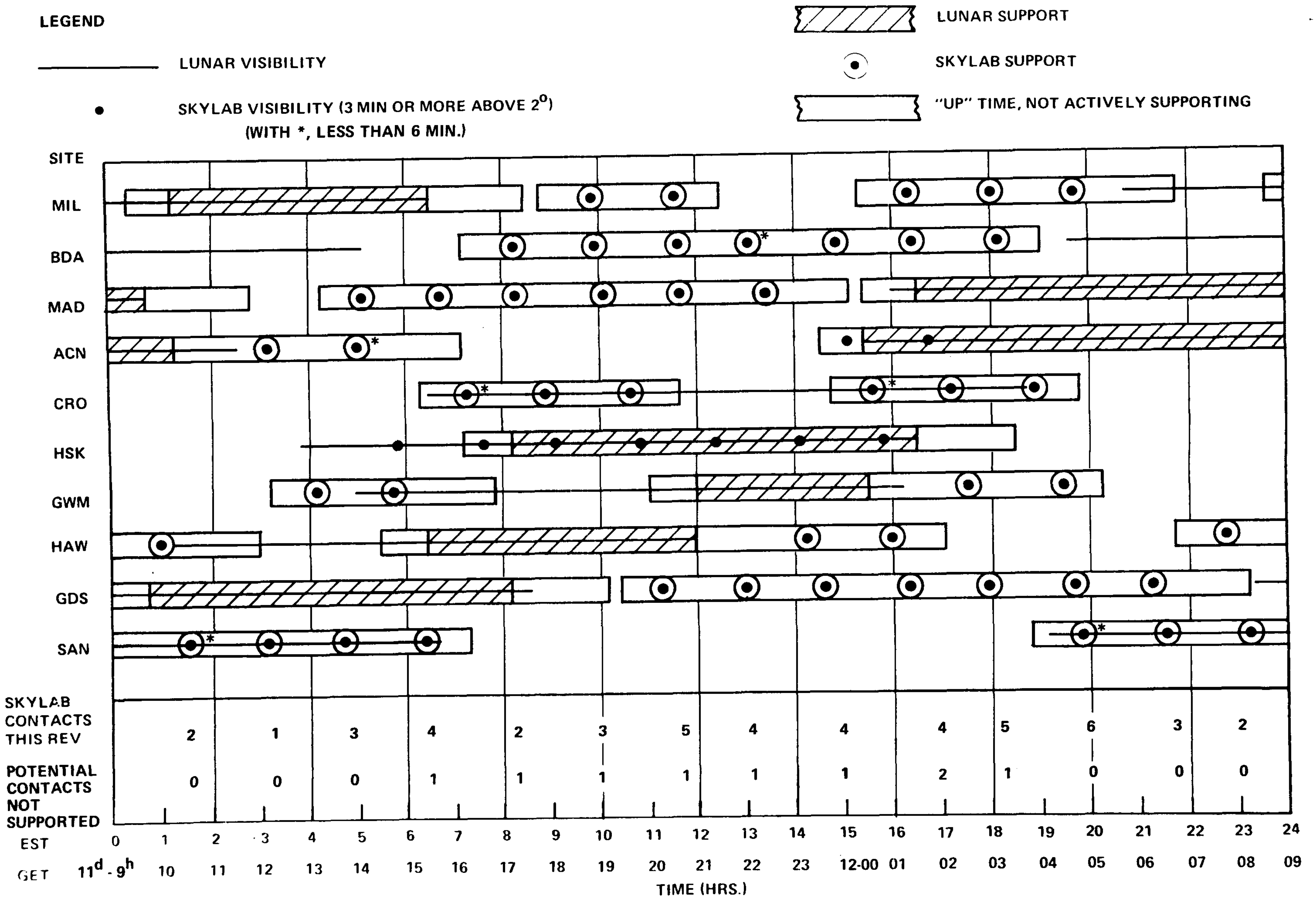


FIGURE B-3 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 27, 1972
(10 STATION NETWORK)

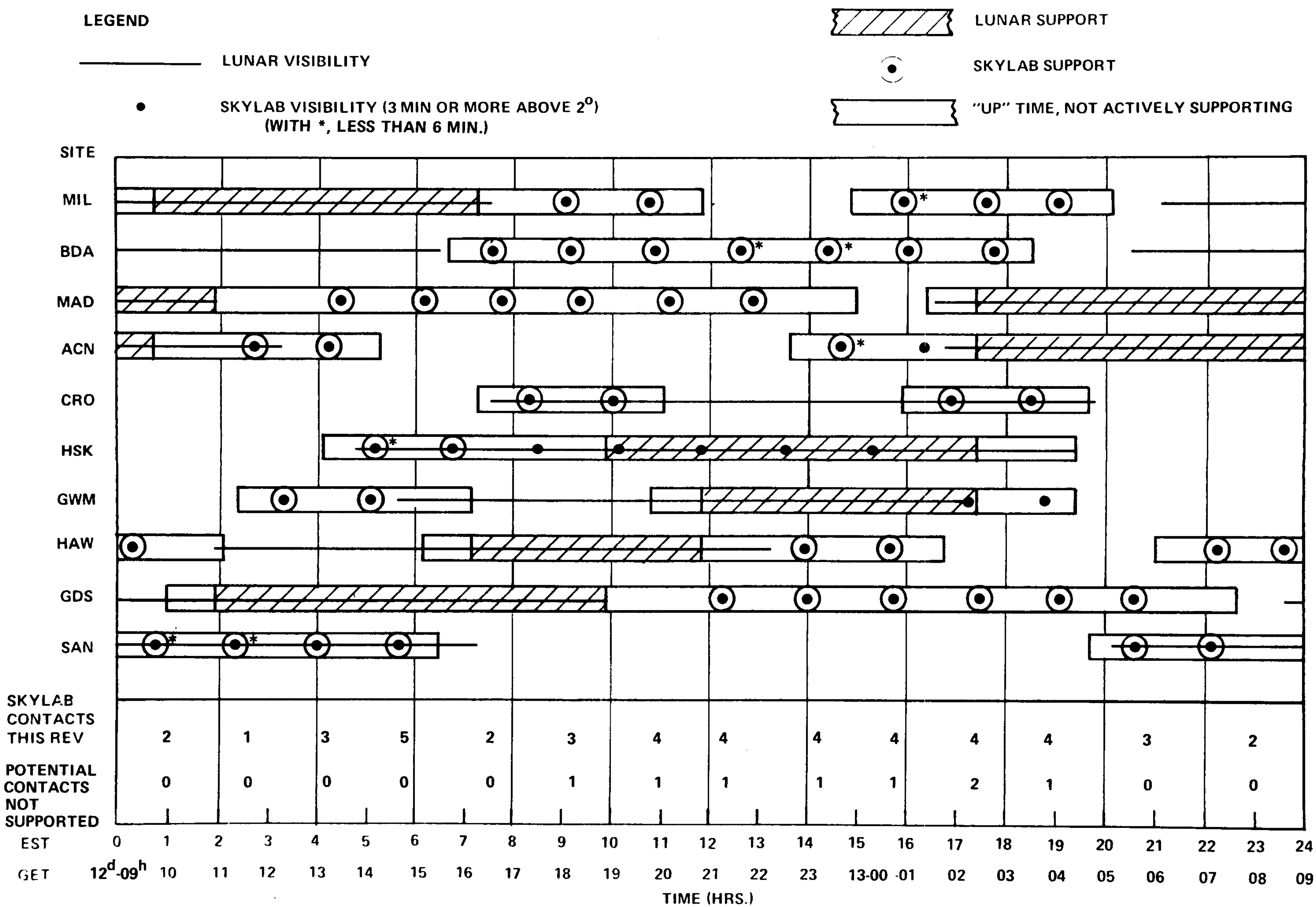


FIGURE B-4 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 28, 1972
(10 STATION NETWORK)

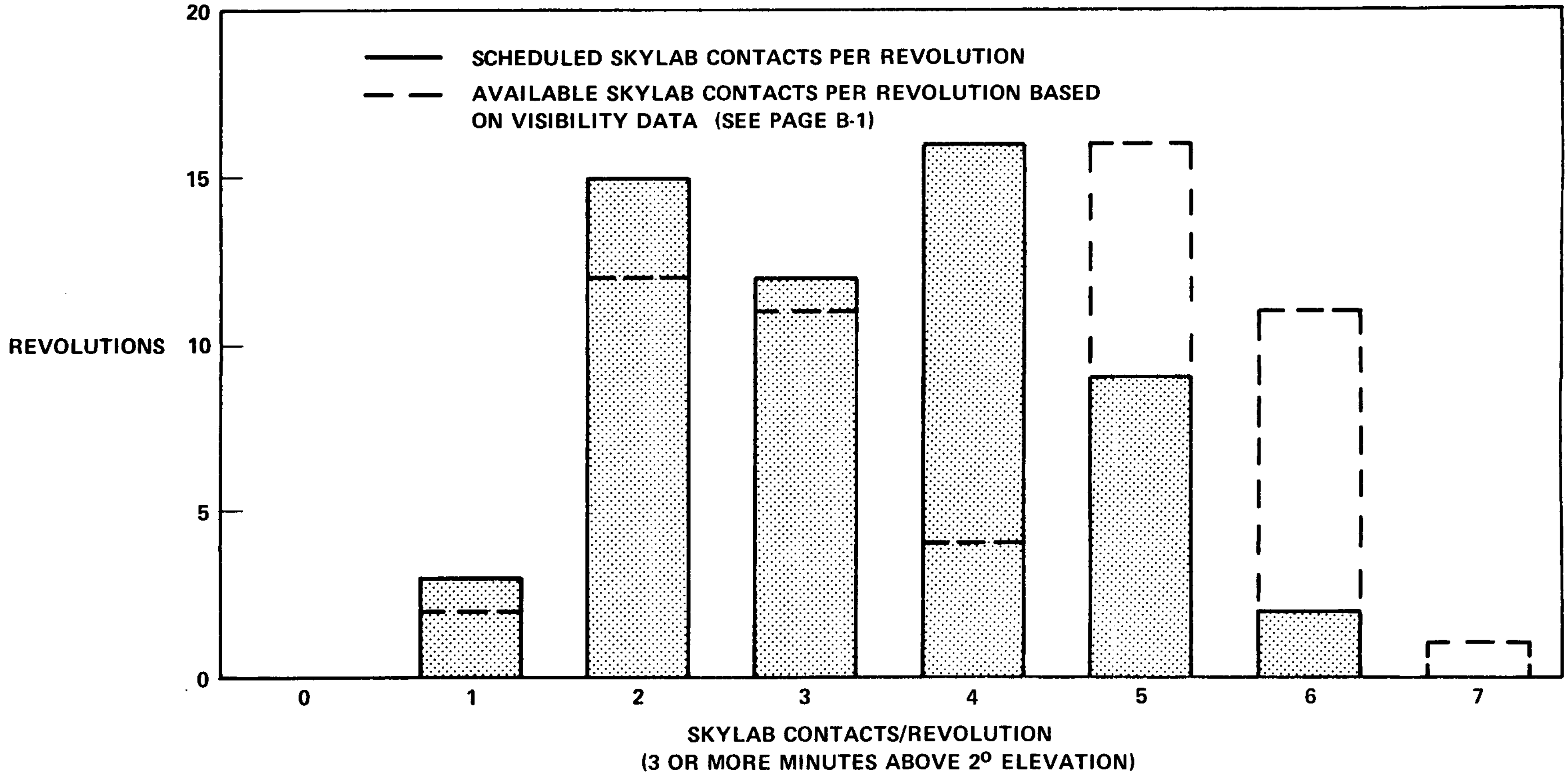


FIGURE B-5 - SKYLAB CONTACTS OVER FOUR-DAY PERIOD

TABLE B-1

STATION SUPPORT TIME

Hours/Day

Station	Day 25	Day 26	Day 27	Day 28	Total
MIL	17	19	18	17	71 Hrs.
BDA	12	12	12	12	48
MAD	21	21	22	23	87
ACN	16	16	16	16	64
CRO	9	11	11	7	38
HSK	11	13	12	15	51
GWM	15	16	14	13	58
HAW	15	19	17	16	67
GDS	21	20	23	22	86
SAN	13	12	12	11	48
	150	159	157	152	618

Average/station/day = 15.5 Hrs.

TABLE B-2

POTENTIAL SKYLAB CONTACTS LOST DUE TO LUNAR SUPPORT

Contacts Lost/Potential Contacts

Station	Day 25	26	27	28	Total
MIL	-/5	-/6	-/5	-/5	-/21
BDA	-/7	-/7	-/7	-/7	-/28
MAD	1/7	1/6	-/6	-/6	2/25
ACN	2/4	2/4	2/4	1/4	7/16
CRO	-/5	-/6	-/6	-/4	-/21
HSK	7/7	7/7	7/7	5/7	26/28
GWM	-/4	-/4	-/4	2/4	2/16
HAW	-/5	-/5	-/4	-/5	-/19
GDS	1/7	-/7	-/7	-/6	1/27
SAN	-/7	-/8	-/7	-/6	-/28
	11/58	10/60	9/57	8/54	38/229
					= 17%

TABLE B-3

GAPS FOR SKYLAB ATM SUPPORT EXCEEDING ONE HOUR

Gap Length (min)	Actual	Unavoidable*
60-69	16	10
70-79	6	2
80-89	4	3
90-99	--	--
100-109	--	--
110-119	--	--
120-129	2	2
130-139	1	1
	29	18

*The "unavoidable" column shows the number of gaps of the indicated length without considering the need for simultaneous lunar support. The difference between the actual and unavoidable gaps reflects the penalty in terms of Skylab support caused by simultaneous lunar support.

Note - For Skylab ATM support, only contacts of at least 6.0 minutes (2° elevation) were considered (see text).

APPENDIX C

TRIAL SCHEDULING FOR A NINE-STATION MSFN

This appendix differs from Appendix B only in respect to considering a nine-station network instead of a ten-station network. Guam, in addition to Texas and Canary, has been deleted in this exercise. The assumed lunar support by an 85' and a 30' station around the clock has been retained. The formats of the figures and tables are identical to those of Appendix B.

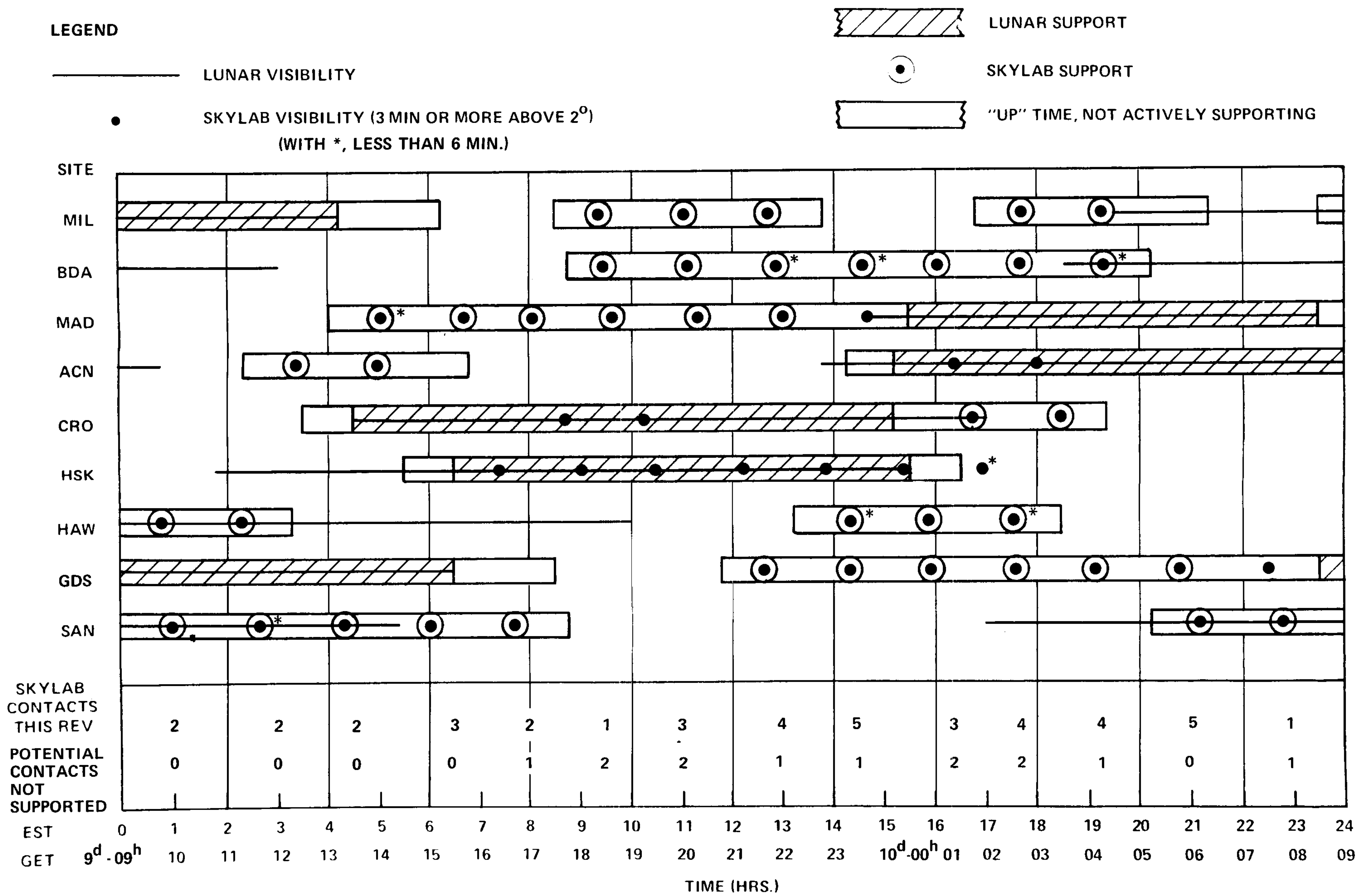


FIGURE C-1 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 25, 1972
(9 STATION NETWORK)

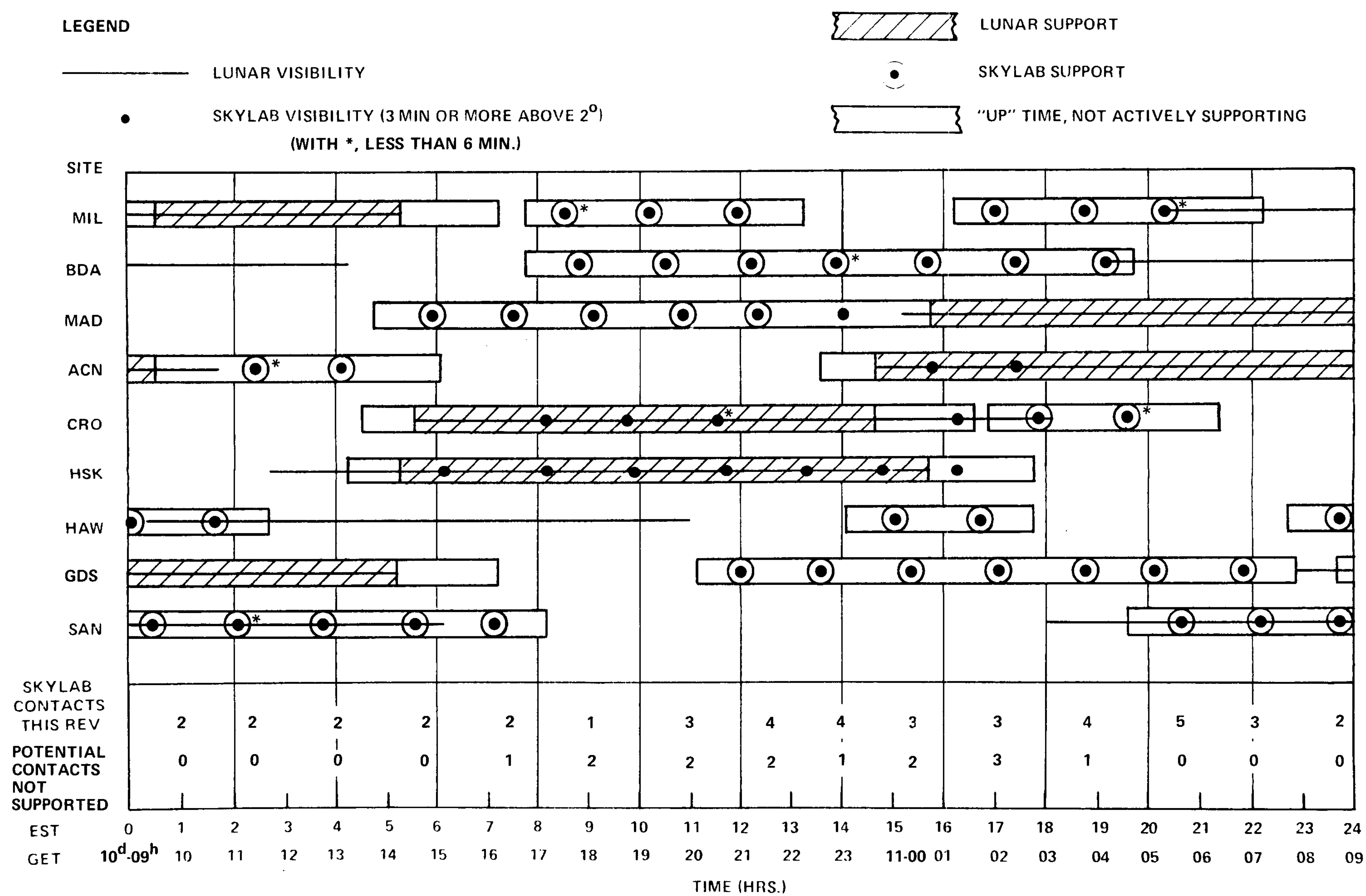


FIGURE C-2 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 26, 1972
(9 STATION NETWORK)

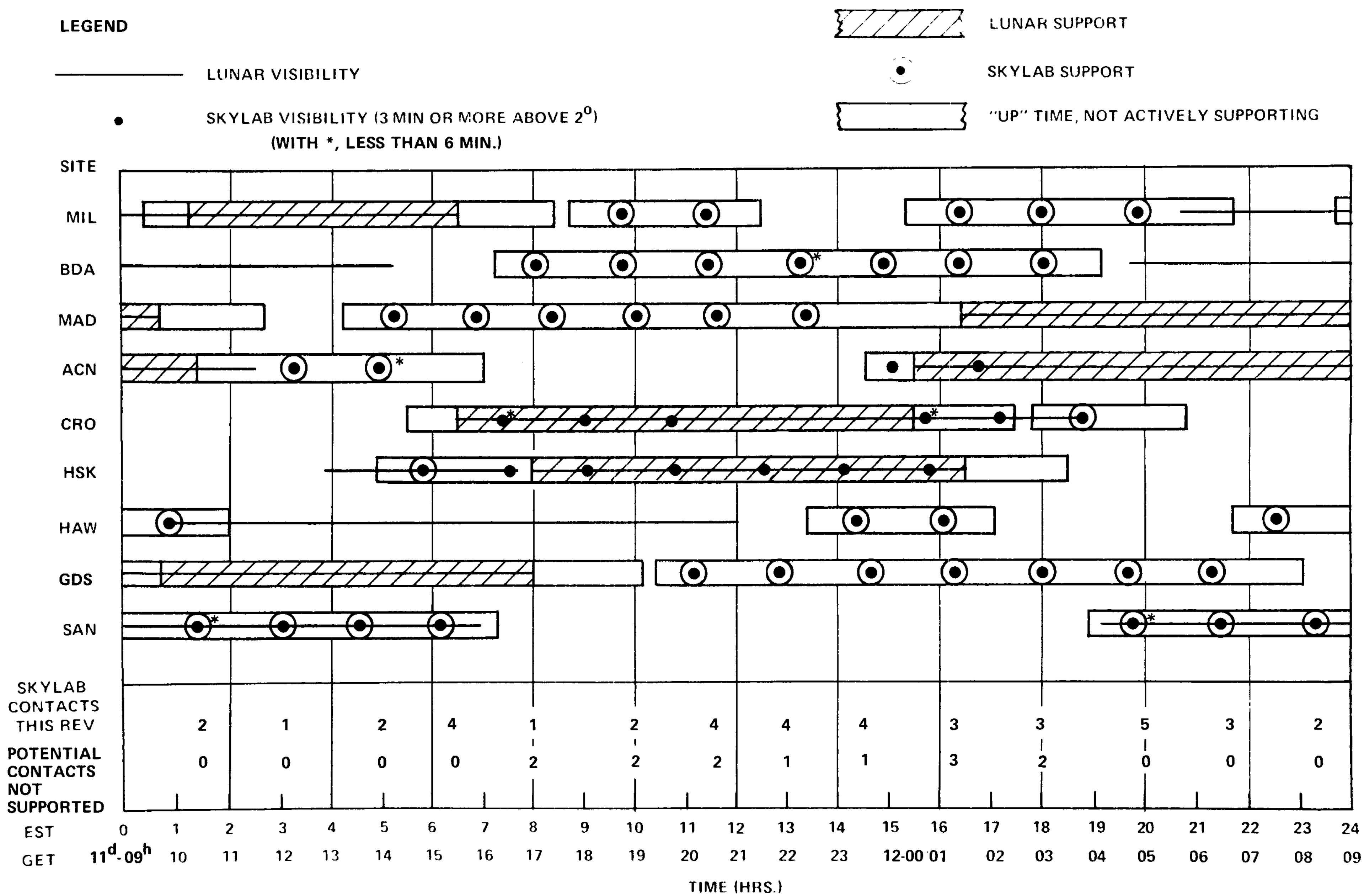


FIGURE C-3 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 27, 1972
(9 STATION NETWORK)

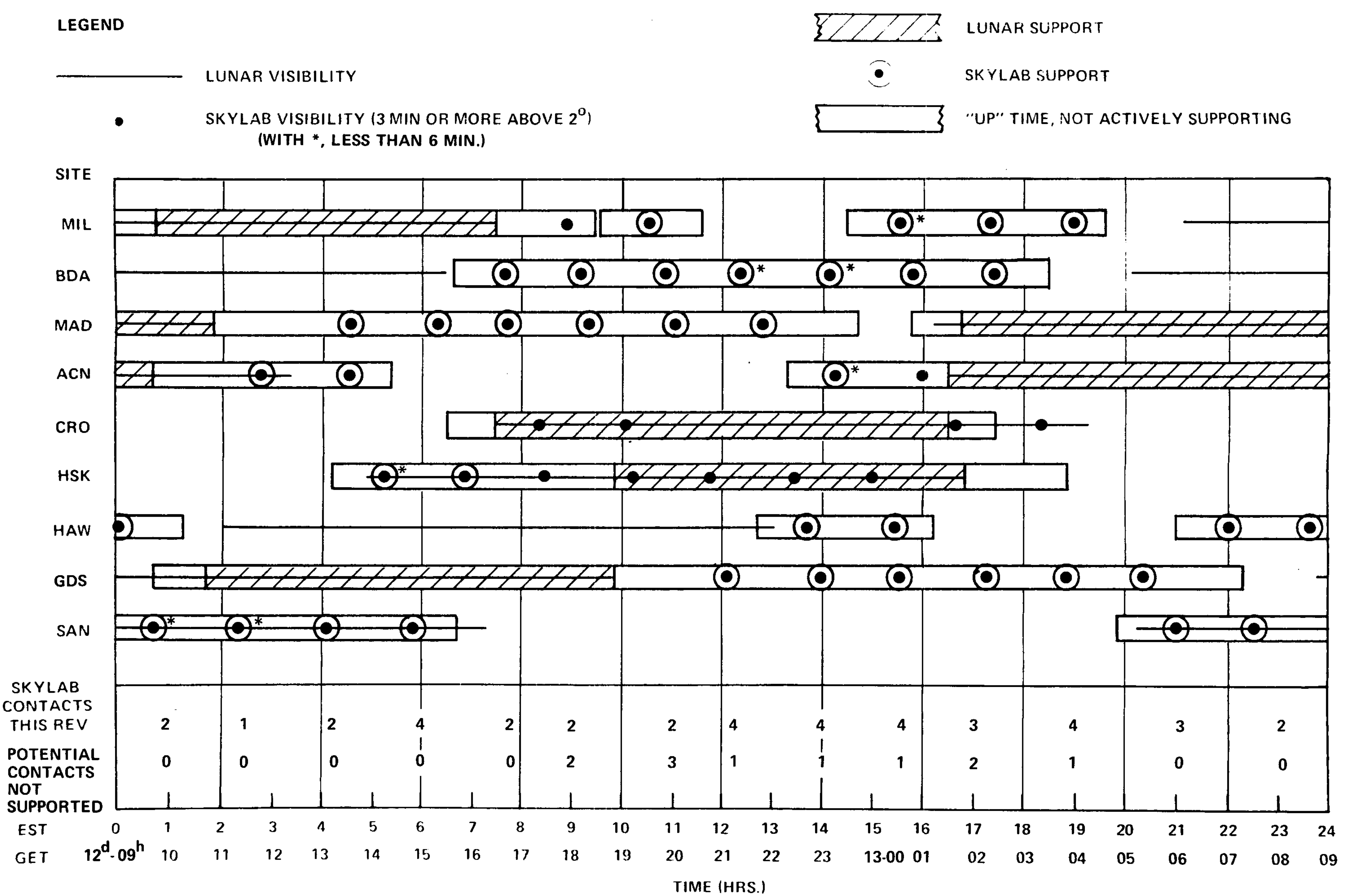


FIGURE C-4 - POSSIBLE LUNAR AND SKYLAB SUPPORT BY MSFN - JULY 28, 1972
(9 STATION NETWORK)

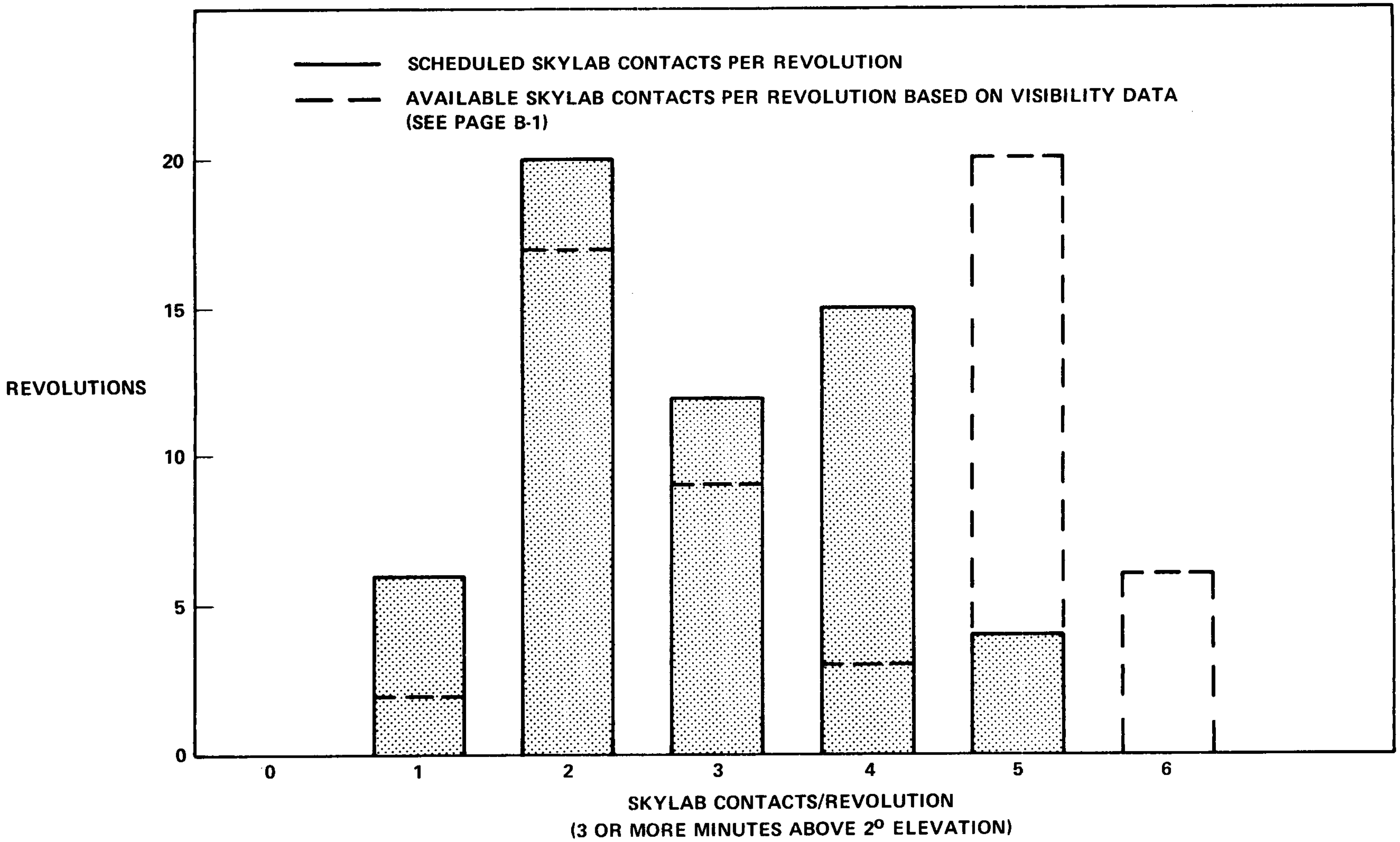


FIGURE C-5 - SKYLAB CONTACTS OVER FOUR-DAY PERIOD

TABLE C-1

STATION SUPPORT TIME

Hours/Day

Station	Day 25	26	27	28	Total
MIL	17	19	18	17	71 Hrs.
BDA	12	12	12	12	48
MAD	21	21	22	23	87
ACN	16	16	16	16	64
CRO	19	18	16	11	64
HSK	11	14	14	15	54
HAW	8	8	8	8	32
GDS	21	20	23	22	86
SAN	13	12	12	11	48
	138	140	141	135	554

Average/station/day = 15.4 Hrs.

TABLE C-2

POTENTIAL SKYLAB CONTACTS LOST DUE TO LUNAR SUPPORT

Contacts Lost/Potential Contacts

Station	Day 25	26	27	28	Total
MIL	-/5	-/6	-/5	1/5	1/21
BDA	-/7	-/7	-/7	-/7	-/28
MAD	1/7	1/6	-/6	-/6	2/25
ACN	2/4	2/4	2/4	1/4	7/16
CRO	2/5	4/6	5/6	4/4	15/21
HSK	7/7	7/7	6/7	5/7	25/28
HAW	-/5	-/5	-/4	-/5	-/19
GDS	1/7	-/7	-/7	-/6	1/27
SAN	-/7	-/8	-/7	-/6	-/28
	13/54	14/56	13/53	11/50	51/213
					= 24%

TABLE C-3

GAPS FOR SKYLAB ATM SUPPORT EXCEEDING ONE HOUR

Gap Length (min)	Actual	Unavoidable*
60-69	19	9
70-79	21	7
80-89	4	3
90-99	--	--
100-109	--	--
110-119	--	--
120-129	2	2
130-139	1	1
	47	22

*The "unavoidable" column shows the number of gaps of the indicated length without considering the need for simultaneous lunar support. The difference between the actual and unavoidable gaps reflects the penalty in terms of Skylab support caused by simultaneous lunar support.

Note - For Skylab ATM support, only contacts of at least 6.0 minutes (2° elevation) are considered (see text).

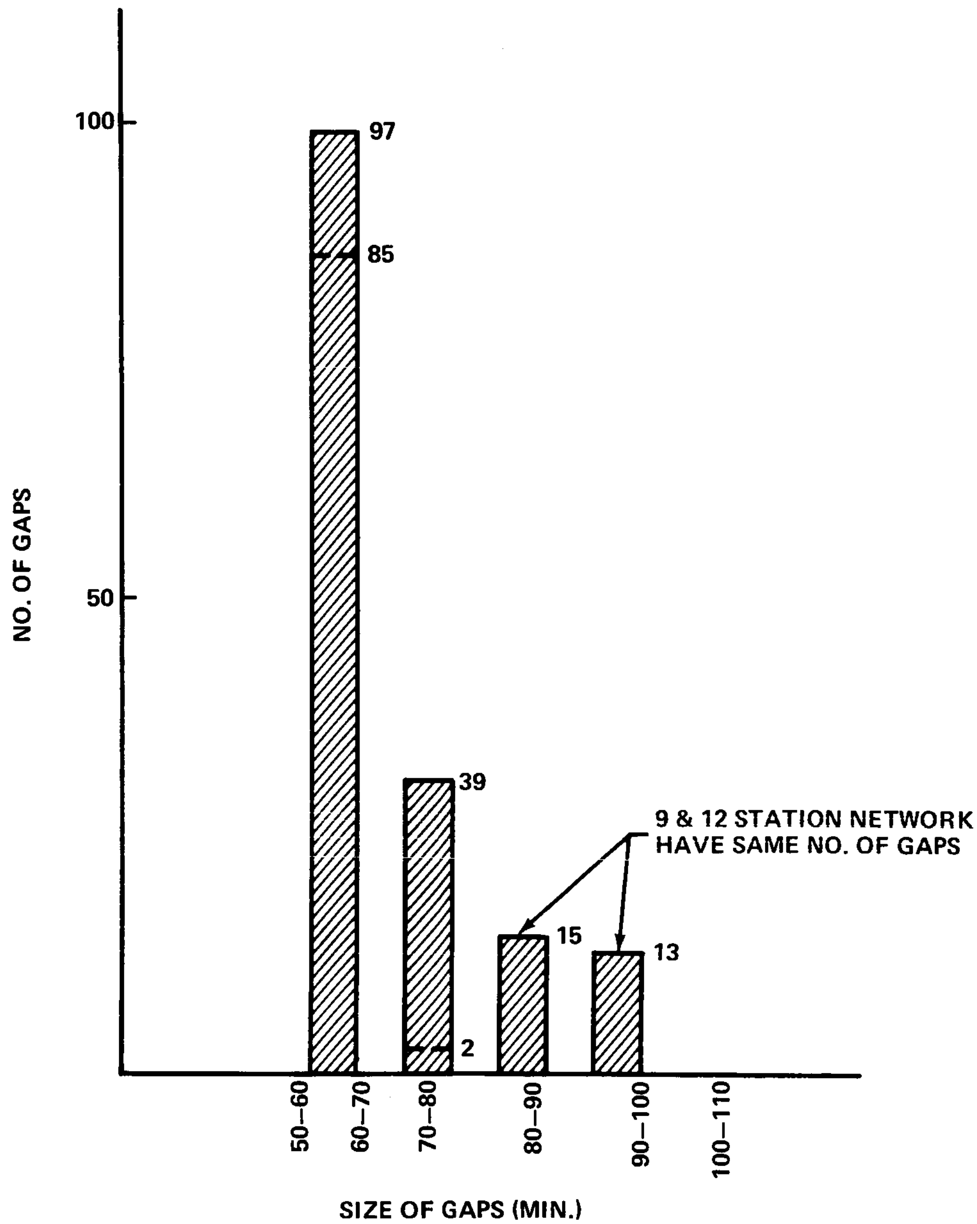


FIGURE 4 - NUMBER OF GAPS VS. SIZE OF GAPS

—— 12 STATIONS
– – 9 STATIONS (–CYI, GWM, TEX)
(3 MINUTE MINIMUM CONTACTS)

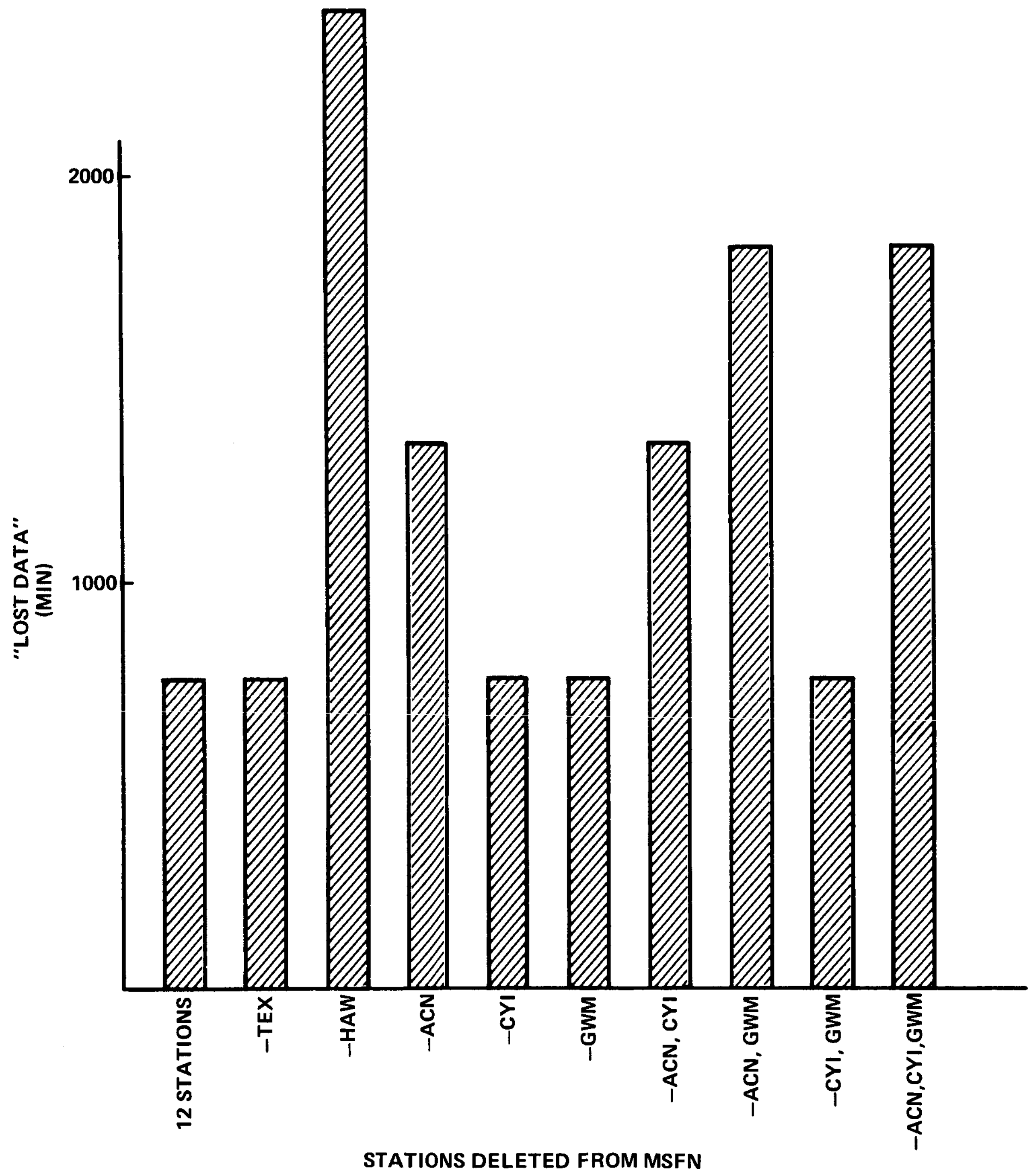


FIGURE 5 - "LOST DATA" VS. STATIONS DELETED FROM MSFN
(6 MIN MINIMUM CONTACTS)